

An Inverse Almost Ideal Demand System for Oysters in the United States: An Empirical Investigation of the Impacts of Mandatory Labels*

Cheikhna Dedah
Graduate Assistant
Department of Agricultural Economics and Agribusiness
Louisiana State University
Baton Rouge, LA 70803
Email: couldd1@lsu.edu

Walter R. Keithly, Jr.,
Associate Professor
Coastal Fisheries Institute
Louisiana State University
Baton Rouge, LA 70803
Email: walterk@lsu.edu

Hamady Diop, PhD
Assistant Professor
Louisiana Sea Grant College Program
Louisiana State University
Baton Rouge, LA 70803
Email: hdiop1@lsu.edu

Richard F. Kazmierczak, Jr.,
Professor
Department of Agricultural Economics and Agribusiness
Louisiana State University
Baton Rouge, LA 70803
Email: rkazmierczak@agctr.lsu.edu

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INTRODUCTION

There are three primary oyster-producing regions in the United States: the Gulf of Mexico, the Pacific, and Chesapeake Bay. The predominant species harvested from the Gulf and Chesapeake is the Eastern oyster (*Crassostrea virginica*) while the Pacific oyster (*Crassostrea gigas*) represents the primary species harvest on the west coast (i.e., California through Alaska). During 1985-2003, annual oyster harvests from the Gulf and Chesapeake, combined, averaged approximately 27 million pounds annually while harvests from the Pacific averaged approximately six million pounds. In addition to the domestic production, there is a significant quantity of imported product. During 1985-2003, these imports averaged 6.5 million pounds annually.¹

California, in response to health concerns, initiated a program on March 1991 which required anyone selling oysters to notify potential consumers that the “consumption of raw oysters can cause serious illness and death among people with liver disease, chronic illness, or weakened immune systems”. This mandatory warning label, followed shortly thereafter by a similar warning in other states, including Louisiana and Florida, received extensive media coverage.

¹ Combined, these three regions and imports represent in excess of 90% of the available supply of oysters for consumption in the United States.

These warning labels and associated media attention were in response to an increasing frequency of illnesses and deaths linked to *Vibrio vulnificus*, a naturally occurring bacterium found in the Gulf of Mexico waters.² Virtually all oysters harvested from these waters during the warmer summer months exhibit some concentration of the bacterium. While consumption of *Vibrio*-laden raw oysters is relatively innocuous among healthy individuals, it can lead to serious illness and even death among individuals with immunocompromised systems (FAO, 2005). Since the Center for Disease Control began to tracking *V. vulnificus* cases in 1995, 30 to 40 cases have been reported each year, nearly all linked to the consumption of raw oysters harvested from the Gulf.³ With an approximately 50% fatality rate, *V. vulnificus* exhibits the highest fatality to case ratio of any foodborne pathogen (FAO, 2005).

The impacts of these warning labels and associated media coverage have not been well documented. In one of the few studies which examined the issue, Keithly and Diop (2001a,b) analyzed the impact of warning labels on the Gulf and Chesapeake ex-vessel prices. The authors reported a price reduction for the Gulf product of \$0.86 per pound in the summer months and a slightly less reduction (\$0.63 per pound) in the winter months, *ceteris paribus*. A similar decline in the price of Chesapeake product in the winter season was reported by the authors.

The primary goal of this analysis is to expand upon the work of Keithly and Diop (2001a,b) by considering the impact of warning labels in a complete demand framework. This is relevant given the fact that warning labels imposed on one product can have negative or positive impacts on related products that compete for the consumer's limited budget. An ancillary goal is to

² While *Vibrio vulnificus* was first identified in the 1970s (FAO, 2005), it apparently received little attention until 1991.

³ Estimates prior to 1995 are "sketchy" since the Center for Disease Control did not track cases in earlier years.

examine the cross-quantity substitution effect that changes in oyster production in one region would be expected to have on the prices of products produced in other regions.

In order to achieve these goals, an Inverse Almost Ideal Demand System (IAIDS) model for domestic and imported oysters is estimated. The paper is organized as follows. The theoretical framework for the IAIDS model is presented in the next section of the paper. Following that, the model used in the analysis is given. Then, the data used in the analysis are presented and discussed along with estimation considerations. Results and relevant discussion is then presented. A summary of the main findings is presented in the last section of the paper.

THEORETICAL CONSIDERATIONS

When modeling a complete demand system, the traditional almost ideal demand system (AIDS) model is appropriate when the assumption of predetermined market prices is satisfied (Deaton and Muellbauer, 1980). However, if quantity is considered exogenous while price is endogenous, then the inverse almost ideal demand system (IAIDS) becomes a more appropriate modeling tool. In the IAIDS model, the consumer preferences are derived from the distance function and not from the cost function as in the AIDS model. It represents the amount that all the consumed quantities need to change in order to attain a particular level of utility (Eales and Unnevehr, 1994).

The IAIDS model function is given by

$$(1) w_i = \alpha_i + \sum_j \gamma_{ij} \ln q_j + \beta_i \ln Q$$

w_i is the budget share for the i -th commodity and q is the quantity demanded and the Q is the quantity scale index. It is given by the equation

$$\ln Q = a_0 + \sum_k \alpha_k \ln q_k + 1/2 \sum_k \sum_j \gamma_{kj} \ln q_k \ln q_j$$

For the IAIDS model to be theoretically meaningful, the following conditions has to be met:

a- Homogeneity

$$\sum_j \gamma_{ij} = 0$$

b- Symmetry

$$\gamma_{ij} = \gamma_{ji}$$

c-Adding up

$$\sum_i \gamma_{ij} = 0; \sum_i \alpha_i = 1; \sum_i \beta_i = 0$$

Estimating the IAIDS system in equation (1) requires nonlinear estimation methods because the quantity scale index is nonlinear in parameter. To avoid this problem, it is appropriate to use a linear approximation of this index. Among the scale indexes that can be used to estimate the Linear version of the IAIDS model is the Stone Quantity Index given by

$$\sum_i w_i \ln q_i \text{ (similar to the stone price used by Deaton and Muellbauer (1980) in the AIDS}$$

model). However, the performance of this index in the IAIDS model is questionable because the quantities of related products need not move together as would often be the case with prices of related products (Eales and Unnevehr, 1994; Jaffry *et al.*, 2005).

Oyster harvests are largely exogenous in the short run, dependent primarily on environmental factors. Hence, the IAIDS model may be more appropriate for modeling a complete demand system for oysters than the more-traditional AIDS model.⁴ Such a model is employed in this study. Furthermore, the Laspeyre version of the stone quantity index is used to estimate the model. This index is given by:

$$\ln Q^s_t = \sum w^0_{it} \ln \left(\frac{q_{it}}{q^0_i} \right)$$

MODEL SPECIFICATION

The IAIDS, as specified, is comprised of four share equations: one for each of the three major producing regions in the United States and one for imports. The general share equation adjusted for a seasonal trend and a nonlinear intercept shifter is given by:

$$w_{it} = \alpha_i + \sum_{j=1}^4 \gamma_{ij} \ln q_{jt} + \beta_i \ln Q + \sum_{s=1}^4 \delta_{is} \theta_{ts} + \varphi_i * Vib + \lambda_i * Trend + \varepsilon_{it} \quad i, j = 1, 2, 3, 4$$

w_{it} is the expenditure share for the oyster harvested in region i at time t , q_j is per capita quantity of oyster supplied by region j at time t , Q is the Laspeyres quantity index, θ_{ts} represents a binary variable used to “capture” the seasonal effect on share (1 when season is s and 0 otherwise), and Vib ⁵ is a binary variable included to “capture” the change in the demand due to mandatory warning labels (equal to 0 prior to the second quarter of 1991 and 1 thereafter).

⁴ A larger issue is, perhaps, separability when examining a very narrowly defined product. Attention is given to this factor in a subsequent section.

⁵ The second quarter of year 1991 is chosen to be the starting period for the *Vibrio* dummy variable because that coincides with the period when California mandated warning labels

Finally, the model includes a time trend (*Trend*) to capture evolving changes in tastes and preferences.

The IAIDS model meets the demand theory requirement when the following constraints hold:

Homogeneity: $\sum_j \gamma_{ij} = 0$

Symmetry: $\gamma_{ij} = \gamma_{ji}$

Adding up: $\sum_i \gamma_{ij} = 0$; $\sum_i \alpha_i = 1$; $\sum_i \beta_i = 0$; $\sum_i \delta_{is} = 0$; $\sum_i \varphi_i = 0$; $\sum_i \lambda_i = 0$

DATA AND ESTIMATION METHODS

Data

Harvest quantities and values (at dockside) are derived from data maintained by the National Marine Fisheries Service.⁶ Import data is derived from U.S. Department of Customs sources. Finally, population estimates are provided by the U.S. Census Bureau.

Annual Gulf oyster harvests exceeded 20 million pounds annually in the mid-1980s but fell by the early 1990s to about 12 millions (Figure 1). This decline was primarily the result of unfavorable environmental conditions. Production since the mid-1990s, however, has approached figures reported during the mid 1980s. Annual Pacific production averaged approximately 11 million pounds during the late 1980s before decreasing to about 8.5 millions

⁶ A portion of the Pacific production is collected only on an annual basis. To include these nonspecified annual quantities into the calculation, they were proportionally distributed on the each month. For instance, the new harvest quantity for month i will equal its current quantity (q_i) plus its share of the annual nonspecified quantity.

annually in the 1990s. Since the turn of the decade, Pacific production has averaged more than 11 million pounds annually. Annual production from the Chesapeake Region declined from high of 12 million pounds in the late 1980s to as low of less than one million pounds by 1993. This sharp decline in the Chesapeake production is has been attributed to dermo (*Perkinses marinus*) and MSX (*Haplosporidium nelsoni*) (Jordan, 1998). Finally imports tended to fluctuate in the relatively narrow range of 5 million to 7 million pounds during the 1985-1999 period before increasing to about 8 million pounds in the more recent years.

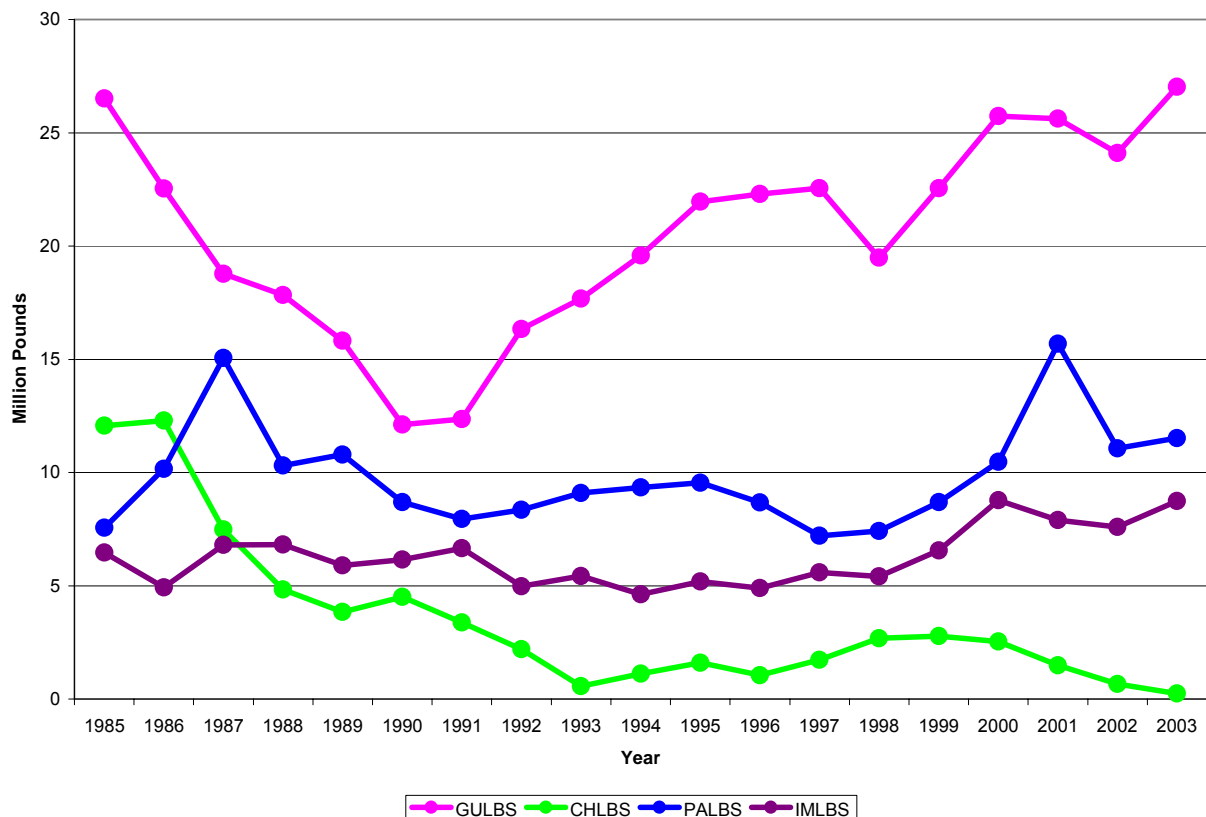


Figure 1: Annual U.S. oyster harvests by region and imports of oysters

Prior to 1991, annual Gulf and Chesapeake deflated ex-vessel prices tended to “mirror” one another (Figure 2). Since 1991, however, the prices in these two regions have become decidedly more distinct, with the average price differential generally exceeding \$0.50 per pound and, in

some years, approaching \$1.00 per pound. There are at least two explanations for this finding. First, landings in the two regions have taken different paths since the early 1990s. Chesapeake production, as indicated in Figure 1, has fallen sharply since the early 1990s while Gulf production has been relatively high since the mid 1990s. Second, the impact of warning labels may have had differential impacts on ex-vessel prices in the two regions. The deflated Gulf of Mexico dockside price fell significantly in 1991 despite low landings, providing some preliminary evidence that warning labels have had an impact on the Gulf price. While the deflated Chesapeake price also fell during the early 1990s, the decline was not of the magnitude of that observed in the Gulf.

Prior to the introduction of warning labels, the Pacific ex-vessel price tended to be significantly less than that observed in either the Gulf or the Chesapeake (Figure 2). Since 1991, however, the Pacific price has consistently exceeded the Gulf price and has also often exceeded the Chesapeake price. The import price, by comparison, was extremely stable from 1985 through 1990 (Figure 2). Beginning in 1991, however, the import price began to increase significantly before peaking at \$1.47 per pound in 1995. Since 1995, the deflated import price has gradually declined and has averaged less than \$1.00 per pound since the turn of the decade.

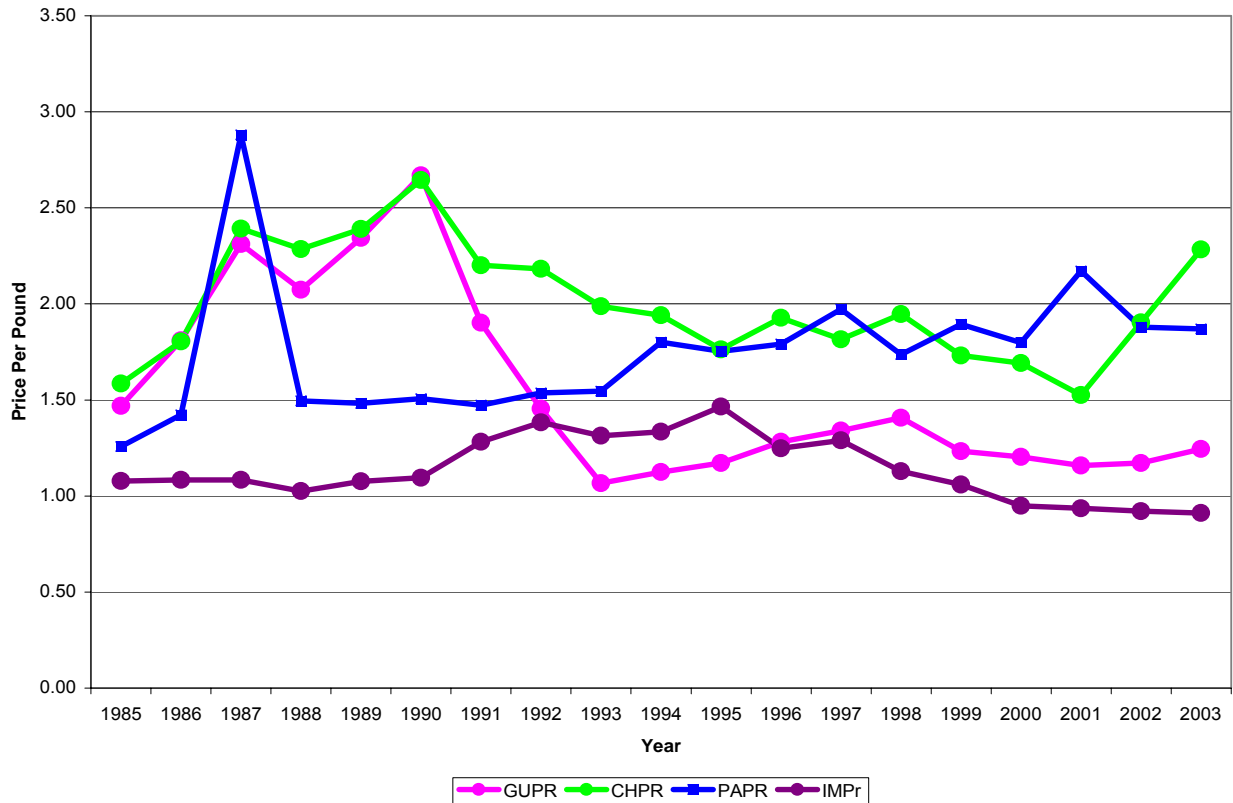


Figure 2: Annual deflated ex-vessel oyster prices by region and import price (1980-84 base year).

For purposes of analysis, all quantity data are expressed on the basis of 1,000 U.S. population.

Some summary statistics of variables used in the analysis are presented in table 1. As indicated, quarterly Gulf harvest averaged 19.4 pounds (per thousand persons) while the mean budget share represented by the Gulf equaled 49.7%. For the Chesapeake, the quarterly harvest averaged 3.5 pounds (per thousand persons) while the corresponding mean budget share was 9.2%. The quarterly harvest in the Pacific averaged 9.4 pounds per thousand persons during 1985-2003 while quarterly imports per thousand persons averaged 5.9 pounds. The corresponding budget shares equaled 28% and 13%, respectively.

Table 1: Summary Statistics Associated With Variables Used in Analysis

Vari able	Mean	Std.Dev	Maximum	Minimum
Gulf landings(lbs/1000 persons)	19.408	5.742	41.47	8.63
Chesapeake landings(lbs/1000 persons)	3.508	5.478	29.12	0.002
Pacific landings(lbs/1000 persons)	9.356	3.623	23.29	2.45
Imports(lbs/1000 persons)	5.935	2.245	13.43	2.51
Gulf share	0.498	0.079	0.63	0.3077
Chesapeake share	0.092	0.110	0.46	0.0001
Pacific share	0.280	0.087	0.55	0.0989
Import share	0.130	0.071	0.36	0.0301

Estimation Considerations

An Inverse Almost Ideal Demand System model (IAIDS), as noted, was estimated based on quarterly time series data covering the period 1985(1)-2003(4). The IADS model is justified on the basis that harvest, at least on a quarterly basis, is largely determined by environmental conditions and is largely unresponsive to price changes. To avoid singularity⁷, one of the share equations is dropped from the analysis. For purposes of this analysis, the import equation was initially deleted and Gulf, Chesapeake, and Pacific shares equations were estimated using seemingly unrelated regression (SUR) procedure to gain efficiency in the estimated parameters. Then, the import equation was added to the model and the Chesapeake equation was dropped. Both homogeneity and symmetry restrictions are imposed on the estimated model. SAS version 9.2 is used to perform the analysis.⁸

⁷ To avoid singularity, season variable four is dropped from each equation.

⁸ While the parameter estimates for the dropped equation could have been recovered via the adding up conditions, there would be no associated standard errors associated with the parameter estimates of the dropped equation. Results were invariant to the deleted equations suggesting that the restrictions were correctly imposed.

RESULTS AND DISCUSSION

The results of the IAIDS model after imposing homogeneity and symmetry restrictions are presented in table 2, and the results of the likelihood ratio (LR) tests associated with the theoretical restrictions placed on the model are presented in table 3. The p-values of the LR tests are large (larger than 0.05); hence, none of the restrictions are binding. This implies that the theoretical restriction conditions imposed on the model appear to be valid.

In general, all the estimated parameters exhibited the theoretical expected signs. With respect to the Gulf share equation, six out eleven estimated parameters were statistically significant at 5% while all estimated parameters associated with the Pacific share equation were statistically significant at 5% level of significance. In the Chesapeake equation, seven parameters were statistically significant at 5% level. Finally six parameters were found to be statistically significant in the import share equation at 5% level of significance. The time trend variable was not significantly different from zero in the Gulf and Chesapeake share equations but was positive and significant in the Pacific equation (0.0009) and negative and significant in the import equation (-0.0013). Furthermore, there was no evidence of serial correlation in any of the individual equations and the individual equation R^2 's ranged from a low of 0.64 (Gulf share equation) to 0.90 (import share equation).

Table2: Estimated parameters from the IAIDS model for oysters ^a

Share/Parameter	α_i	γ_{i1}	γ_{i2}	γ_{i3}	γ_{i4}	β_i	δ_{i1}	δ_{i2}	δ_{i3}	ϕ_i	λ_i	ADJ. Rsquare	DW
Gulf	0.3438* (0.0206)	0.1790* (0.0177)	-0.0072 (0.0052)	-0.1230* (0.0136)	-0.0489* (0.0099)	-0.1220* (0.0332)	0.0041 (0.0175)	0.0054 (0.0219)	-0.0166 (0.0270)	-0.0886* (0.0221)	0.0005 (0.0005)	0.64	1.74
Pacific	0.1746* (0.0179)	-0.1230* (0.0136)	-0.0166* (0.0048)	0.1906* (0.0142)	-0.0511* (0.0086)	0.1726* (0.0308)	0.0539* (0.0159)	0.1013* (0.0209)	0.1233* (0.0254)	0.0904* (0.0204)	0.0010* (0.0005)	0.75	1.78
Chesapeake	0.2886* (0.0185)	-0.0072 (0.0052)	0.0260* (0.0061)	-0.0166* (0.0048)	-0.0022 (0.0028)	-0.0410 (0.0376)	-0.0631* (0.0181)	-0.1270* (0.0225)	-0.1150* (0.0290)	-0.0869* (0.0245)	-0.0002 (0.0006)	0.76	1.83
Import	0.1937* (0.0136)	-0.0492* (0.0092)	-0.0022 (0.0025)	-0.0513* (0.0080)	0.1026* (0.0092)	-0.0095 (0.0166)	0.0051 (0.0083)	0.0200 (0.0120)	0.0079 (0.0142)	0.0852* (0.0107)	-0.0013* (0.0002)	0.91	1.69

Note: Subscript j=1 denotes Gulf, j=2 denotes Chesapeake, j=3 denotes Pacific, j=4 denotes import.

* indicates that the parameter is significant at 5% level of significance.

^a The standard errors are in parentheses.

Table 3: likelihood ratio test for theoretical restrictions

	Chi_square value	P-value
Homogeneity	2.05	0.5612
Symmetry	3.07	0.3816
Homogeneity & Symmetry	3.07	0.8006

The mandatory warning labels and associated media attention (*Vib*) was found to significantly impact the demand for oysters in all three primary U.S. producing regions as well as for the imported product.⁹ With respect to the Gulf and the Chesapeake share equations, the coefficients associated with the binary variable *Vib* are both negative and highly significant. Specifically, the mandatory labels and related media attention were estimated to decrease the budget share of the Gulf product by 8.9% and decrease the budget share of the Chesapeake oyster by 8.7%.

The fact that the negative impact is extended to include Chesapeake product with the impact on that product being roughly equivalent to that for the Gulf product was somewhat unexpected. However, the two products have high degree of similarity in that the harvested products from the two regions represent the same species (*Crassostrea virginica*) and the two products have a similar texture and taste (Glude, 1971). Since consumers cannot easily differentiate between the two products, consumer demand for both products was reduced as a defensive mechanism. Assuming these results are accurate, imperfect information appears to have been costly to the harvesters of the Chesapeake product. Results reported in table 2 also suggest that the Pacific share increased by approximately 9% as a result of warning labels. A similar increase (8.5%) was observed with respect to the import share.¹⁰

⁹ To investigate whether the impact of warning labels declined over time, an alternative functional form, similar to that employed by Mazzocchi et al. (2004) was also considered. The authors used the following function of the intercept to allow for time-varying effect of the BSE scare on beef consumption in Italy.

$\alpha_{it}^* = \dots + b_t d_{zt} (1 + \log t_z^*)^c$ where d_{zt} is equal 1 when $t \geq z$ and 0 otherwise. $t_z^* = t - z + 1$. If the estimated parameter c is zero the function collapses back to a simple binary variable. Results from this investigation suggested that a constant intercept shifter was appropriate (i.e., the estimated parameter c was highly insignificant).

¹⁰ The AIDS model assumes separability in the utility function of the goods employed in the analysis. This, of course, is a concern when the goods being considered in the analysis are narrowly defined (e.g., oysters). Given that the additivity condition requires that the parameter estimates sum to zero, there is the concern that results are merely and artifact of this condition. To examine this is some additional detail, the starting point associated with the variable *Vib* was modified by two years in both directions (i.e., 1989 and 1993). When these changes were made, the parameter estimates associated with the variable *Vib* in most cases became statistically insignificant

Uncompensated price and scale flexibilities along with the appropriate standards errors are reported in table 4. All flexibility estimates were calculated at the sample means. As indicated, all own price flexibilities were found to be negative as theoretically expected. All own price flexibility estimates were less than one in absolute value, indicating that all four oyster products are price inflexible. A one percent increase (decrease) in the Gulf harvest was found to decrease (increase) the normalized Gulf ex-vessel price by approximately 0.76%. A similar change occurs in the price of Chesapeake oysters as its own landings increase (decrease) by one percent. All cross price flexibilities were found to be negative which classifies all products as gross substitutes. The Gulf product was found to exhibit a relatively strong cross-quantity substitution effect with the imported product (-0.41) and Chesapeake product (-0.30) and relatively low cross-quantity substitution effect with the Pacific product (-0.13). The cross price flexibilities for the Chesapeake product reveal that a change in the quantity of Chesapeake product would have very low impact on the ex-vessel price of products harvested in other regions. This is to be expected, given the relatively low harvests in the Chesapeake. The Pacific product was found to have a strong cross-quantity substitution effect with the Gulf product (-0.32) as well as the imported product (-0.41) and the Chesapeake product (-0.31). Finally, the imported product was found to have only a moderate cross-quantity substitution impact on oysters produced in the United States. In general, a ten percent increase (decrease) in the imported product was found to culminate in no more than a 13% decrease (increase) in the ex-vessel price of domestic product produced in any region. The scale flexibilities reported in table 4 suggest that the Gulf, Chesapeake, and imported products can be classified as necessities while the Pacific product can be classified as a luxurious good.

Table4: Uncompensated Price Flexibilities ^a

	GUQ	CHQ	PAQ	IMQ	Scale
GUPR	-0.762* (0.045)	-0.037* (0.010)	-0.316* (0.036)	-0.130* (0.024)	-1.25* (0.067)
CHPR	-0.299 (0.222)	-0.759* (0.060)	-0.305* (0.139)	-0.082 (0.063)	-1.45* (0.409)
PAPR	-0.133 (0.068)	-0.003 (0.016)	-0.147* (0.064)	-0.102* (0.036)	-0.38* (0.109)
IMPR	-0.221* (0.079)	-0.023 (0.017)	-0.415* (0.072)	-0.221* (0.079)	-1.07* (0.128)

Note: quantities for the Gulf, Chesapeake, Pacific, and imported oysters are represented by "GUQ" ; "CHQ"; "PAQ"; and "IMQ" respectively.

prices for the Gulf, Chesapeake, Pacific, and imported oysters are represented by "GUPR" ; "CHPR"; "PAPR"; and "IMPR" respectively.

^a The standard errors are in parentheses.

* indicates parameter estimate is significant at 5% level.

CONCLUSIONS

The IAIDS model developed in this paper shows that the mandatory warning labels on the Gulf product had a significant impact on how consumers allocate their incomes among oyster products. The model shows a shift in the consumer preferences from the Gulf and the Chesapeake products to the Pacific and imported products. Specifically, model results suggest a decline in the Gulf and Chesapeake shares by about 9% and a corresponding increase in the Pacific and import shares.

The estimated cross price flexibilities suggested that the Gulf and Chesapeake products have strong quantity-substitution effect on other products; implying that the prices of Chesapeake and the imported products are highly influenced by changes in harvests of the Gulf and Pacific

products. A small change in per capita harvests of either the Gulf and Pacific product would reduce (increase) the per pound price of the Chesapeake and import products. The estimated value of cross price flexibility for the Pacific with the Gulf is (-0.32), a small change in the per capita harvest of the Pacific product would have a noticeable impact on ex-vessel Gulf price.

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